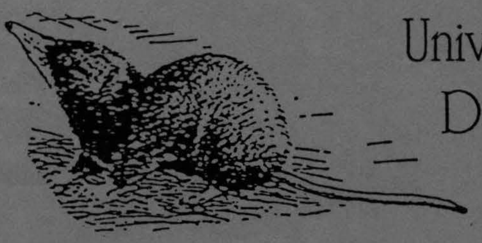

University of North Dakota
Department of Biology
Seminar 1993

"Demography and Use of Space by a
Small Mammal Community in
Itasca State Park, Minnesota"

Neal T. Butt
M.S. Candidate
Department of Biology, University of North Dakota

Friday, May 21, 1993
12:00 Noon
Room 105 Starcher Hall

EVERYONE WELCOME!!!

DEMOGRAPHY AND USE OF SPACE BY A SMALL MAMMAL COMMUNITY IN ITASCA STATE PARK, MINNESOTA

by

Neal T. Butt

Bachelor of Science
University of New Mexico, 1989

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota

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This thesis, submitted by Neal T. Butt in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

[illegible]
(Chairperson)

Albert J. Fivizzani

Richard D. Crawford

This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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ABSTRACT

One of the most interesting and popular areas of study in the Great Plains is the investigation of small mammals and their associated ecological relationships. The objective of this study was to determine the species composition, home range, and sex ratio of selected small mammals inhabiting three habitat types: upland aspen (Populus spp.) forest, adjacent wet meadow, and the ecotonal area between them. This research was carried out at Itasca State Park, Minnesota from June through August of 1992. Longworth live traps and pitfalls were used in tandem in a 10 x 10 grid with 10 meter spacing. Home range was estimated using the computer program "Home Range." Population densities were calculated using the Schnabel index. Eleven species of small mammals representing 6 families, and 2 orders were captured during 2,384 trap nights. Home range estimates were lower than that reported in the literature. Possible explanations are discussed. Density estimates were similar to that reported in the literature. Distribution of small mammals was affected by many factors including, food, cover, moisture, vegetation, and predators.

Clethrionomys gapperi was the most abundant species in the aspen forest. *Microtus* pennsylvanicus were most common in the wet meadow. *Peromyscus maniculatus* were captured most often in the aspen forest. Insectivores were well represented with 3 different species. *Sorex cinereus* were more abundant in the aspen forest, but trap mortality prevented any recaptures. Three *Sorex arcticus* were captured, in the aspen and wet meadow. *Blarina brevicauda* was most common in the aspen forest.

INTRODUCTION

One of the most interesting and popular areas of study in the Great Plains is the investigation of small mammals and their associated ecological relationships. These studies have been carried out in several habitat types including: forests (e.g. Kirkland and Griffin 1974, Miller and Getz 1977, Dueser and Shugart 1978); riparian woodlands (Geier and Best 1980); forested wetlands (e.g. Getz 1961 a,b,c; Ozoga and Verme 1968); wetlands (e.g. Findley 1951, Spencer and Pettus 1966, Birney et al. 1976); and others.

This intensive study has continued with a concentrated focus in the region of the present study due to the presence of the Lake Itasca Forestry and Biological Station, operated by the University of Minnesota as a research site since 1909.

The study undertaken examined 8 species of the local small mammal community. The objective of this study was to determine the species composition, home range, and sex ratio of selected small mammals inhabiting three habitat types: upland aspen (<u>Populus</u> spp.), adjacent wet meadow, and the ecotonal area between them.

STUDY AREA

The study was conducted in Clearwater County, Minnesota (SW 1/4, Sec.36, T144N, R36W) (Figs. 1 and 2). The study area was within Itasca State Park, which is found in the transition between boreal forest to the north, hardwood forest to the south and east, and prairie 80 kilometers (50 miles) to the west (Buell and Facey 1960, Hansen et al. 1974).

The park is located on the western edge of former glacial Lake Agassiz (Arndt 1977), which was formed when the Red River of the North was dammed by glaciers (Harrison 1965). The resulting landform left behind after Lake Agassiz receded is termed the Itasca Moraine (Wright and Ruhe 1965), and is an influence on the park's topography and soil composition. In addition to the unusual legacy of a glacial lake, the area also has features indicative of advancing and retreating ice sheets (Wadena lobe) in the form of "kettle and knob" topography and large amounts of glacial till deposits (Wright and Ruhe 1965). The area drains into the Mississippi River, whose headwaters are located within the park.

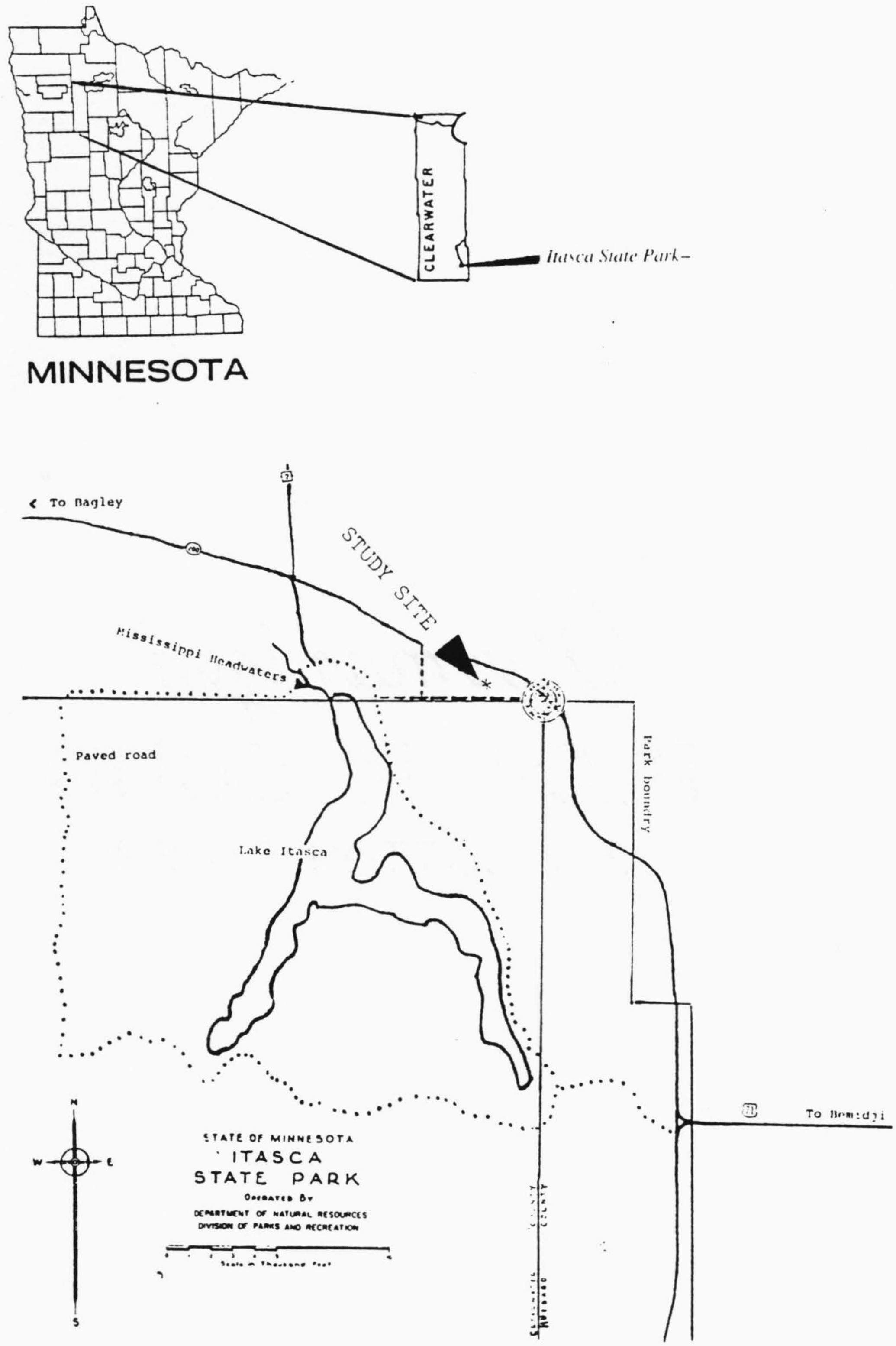

Figure 1. Location of Itasca State Park in Minnesota.

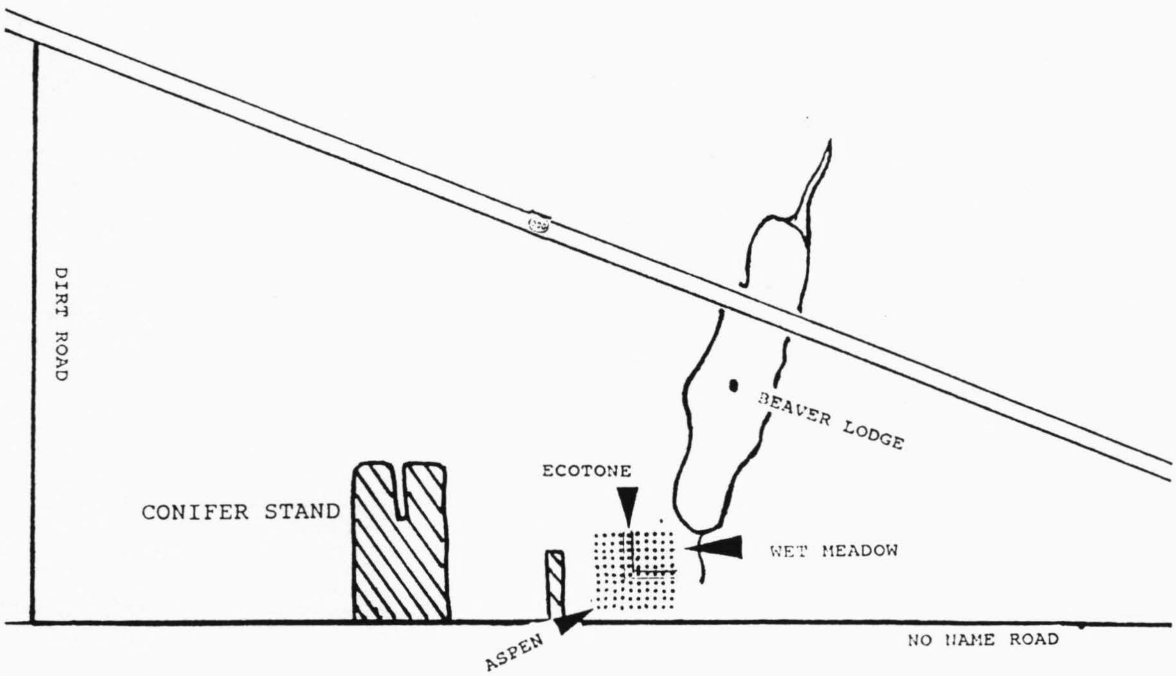

Figure 2. Location of study area within Itasca State Park

The study area lies in a transition zone between two soil types, Nebish-Rockwood and Menahga-Marquette (Nikiforoff et al. 1939). The Marquette series is light-colored, medium-coarse textured soil, derived from calcareous parent materials, and contains sand, gravel, cobbles, and boulders. Usually, Marquette series are associated with the rougher topographic phases of terrain, and are typically well drained. Common plants include mixed pine (*Pinus* spp.) and/or aspen-birch (*Betula* sp.) understories. Stands dominated by aspen (*Populus* spp.) and birch are also common. The Menahga series is a more droughty soil and occurs less frequently. It is tan colored, non-calcareous, sandy soil found on level to gently rolling landscapes. The Menahga consists of well-sorted and excessively drained outwash sand of fine to medium texture. Menahga soils usually only support drought-resistant species like jack pine (*Pinus banksiana*).

Nebish soil is well drained and derived from calcareous loam or clay loam glacial till. This soil occurs on level to rolling landscape. Common plants include northern hardwood species such as sugar maple (*Acer saccharum*) and American basswood (*Tilia americana*). The Rockwood series is a heavy soil, with slightly coarser texture than the Nebish series, ranging from sandy loam to loam. This series is characterized by a less structured B horizon, more effective internal drainage, and lower moisture retentive capacity (Hansen et al. 1974).

The 0.81 ha site chosen for this study was more characteristic of Marquette and Nebish soils, and encompassed two distinct habitat types, upland forest and wet meadow, with an ecotonal area between them. The upland habitat consisted of a stand of young aspen with heavy undergrowth of shrubs, ferns, herbs, and grasses. The most common plants included sweet cicely (*Osmorhiza claytoni*), wild ginger (*Asarum canadense*), false Solomon's seal (*Smilacina racemosa*), goldenrod (*Solidago* sp.), wild strawberry (*Fragaria* sp.), mayflower (*Maianthemum canadense*), black snakeroot (*Sanicula marilandica*), red raspberry (*Rubus idaeus* var. strigosus) and swamp blackberry (*Rubus pubescens*).

The wet meadow habitat was open, dominated by heavy grass and sedge cover, and interspersed with willow (*Salix* spp.). The most common plants included: mint (Labiatae family), swamp smartweed (*Polygonum coccineum*), curled dock (*Rumex crispus*), dogbane (Apocynaceae family), violets (*Viola* spp.), and red raspberry.

The ecotone habitat was defined as the transition zone between the aspen stand and the wet meadow. The most common plants found in this area included: wild ginger, sweet coltsfoot (*Petasites palmatus*), lady ferns (*Athyrium filix-femina*) and bracken ferns (*Pteridium aquilinum*), red raspberry, mint, thistle (Cirsium sp.), and wild strawberry. Approximately half of the study area was comprised of aspen with the remaining area made up of wet meadow and the transitional ecotone between the two habitats.

The surrounding region of Itasca State Park is classified as having a "humid microthermal" climate with moist (snowy) winters and cool summers (Critchfield 1960). Itasca is classified as "dcb" in the Koppen System (Trewartha 1968): "d" means it belongs to the "temperate group" in which the average temperature of at least 4 but less than 8 months exceeds 10^0C; "c" means "continental type" which imposes that the average monthly temperatures of one or more months is less than 0^0C; "b" refers to the "cool" summers which do not exceed 22^0C on average. Total annual precipitation is 64 cm (25.2 inches), of which 40.6 cm (16 inches) falls as summer rain, 12.7 cm (5 inches) as winter snow (Hansen et al. 1974), and the remainder during fall and spring.

METHODS

Capture-recapture techniques were used to assess demographic characteristics of the study population. Longworth live traps and pitfall traps were set out between 23 June and 7 August 1992. A short fall season collection was carried out from 17 October to 21 October 1992. Fifty Longworth live traps and 50 pitfall traps (36 oz coffee cans) were alternated between stations (Pasitschniak-Arts and Gibson 1989) in a 10 X 10 grid with 10 m spacing between traps (Manville 1949, Brown 1967, Kitchings and Levy 1981, Seagle 1985a,b; Huntley and Inouye 1987, Belk et al. 1988), for an area of 0.81 ha. When possible, traps were placed near burrow entrances, under logs, near cavities, and other likely places. Traps were baited with insect larvae, apples, rolled oats, and peanut butter. Cotton batting was placed inside the trap to provide insulation. Animals were toe clipped for later identification of individuals (Melchior and Iwen 1965). Each morning traps were checked for animals which were then examined and data recorded; afterwards, the traps were re-baited. Data collected included: trap coordinates, species, animal number, sex, weight, reproductive status, presence of ticks, date, time, and general weather conditions.

Home range was estimated using the computer program "Home Range" (Ackerman et al. 1990). This program estimates home range area using capture-recapture data by generating a geometric figure around successful trap sites. Different methods of calculation involve different shapes and consequently different estimates. There are three commonly used methods of estimation. The most conservative is the minimum convex polygon method (Hayne 1949). The peripheral capture locations of an animal are connected in such a way that the internal angles of the resulting polygon thus generated do not exceed 180 degrees. It is a pragmatic method which ignores any potential area outside the perimeter circumscribed, and is severely affected by outliers (Ackerman et al. 1990). The second is the harmonic mean estimate. It is a non-parametric method based on the volume under a fitted three dimensional utilization distribution. The distribution is based on harmonic mean values calculated at grid points systematically located throughout the animal's home range (Dixon and Chapman 1980). Sample size must be large so this method could not be used. The bivariate normal (non-circular) ellipse (Jenrich and Turner 1969) estimation method generates an ellipsoid shape regardless of the true pattern of the animals movements. The bivariate ellipse method has two possible variations, with or without outliers included in the calculations. The weighted bivariate normal ellipse excludes outliers from the calculations. A requirement for the program was that to obtain an estimate there had to be at least one capture at three different trap sites to enable the program to generate a closed geometry (i.e. a triangle) for area estimation. Because of sample size constraints, the normal bivariate estimation (95% of captures) was used in this study. Individual animals were considered 'transients' if they were only captured once during the study.

Population density estimates for the dominant species were calculated using the Schnabel (1938) index. Microtus pennsylvanicus did not utilize areas outside the meadow and so its density was estimated for the area of the marsh only (0.203 ha). Peromyscus maniculatus did not utilize areas other than the forest (0.486 ha), and so its density estimate excludes the marsh area in calculations. Sex ratios were calculated for each of the target species captured.

Vegetation was analyzed in 1-m^2 quadrats, at 50 stations chosen randomly. This was done by assigning each of the 100 trap sites a number from 1 to 100 then picking 50 numbers from a random numbers table and associating the last two digits with its corresponding trap. The quadrat was placed 1 m north of each selected trap site to avoid sampling on the path to the trap. Each species within each quadrat was identified and counted. Species not immediately recognizable were labeled (a,b,c,etc.) and identified later. Frequency of occurrence was recorded to describe the vegetation on the grid (Table 1). Plants identified in the field were confirmed in herbaria at Itasca Biological Station and University of North Dakota, using Ownbey (1969), Great Plains Flora Association (1977), and Peterson and McKenny (1968) as references.

RESULTS

Species composition

Eleven species of small mammals representing 6 families and 2 orders were captured during 2,384 trap nights. Four of the species captured were not relevant to

Table 1. Frequency of plant species (mean number per station), by habitat type, Itasca study site, 1992.

PLANT SPECIES	FOREST	ECOTONE	MEADOW
Athyrium filix-femina	0	0.18	0.25
Achillea lanulosa	0	0	0.08
Actea rubra	0.11	0	0
Amelanchier sp.	0.03	0	0
Apocynaceae family	0	0	2.17
Aralia nudicaulis	0.34	0.45	0
Asarum canadense	6.57	5.82	0.25
Aster umbellatus	0.09	0.18	0.58
Betula lutea	0.34	0.36	0
Circuta maculata	0.43	0	0
Cirsium sp.	0	1.64	0.17
Clintonia sp.	0	0.45	0
Aquilegia canadensis	0.03	0	0
Compositae family	0.23	0	0.17
Cornus stolinifera	0.54	0.91	0.08
Corylus americana	0.09	1.09	0
Cyperaceae family	0	0	0.17
Diervilla lonicera	0.29	0	0
Epilobium angustifolium	0.03	0	0.33
Equisetum sp.	0.03	1.0	0.58
Fragaria sp.	3.26	1.82	0.25
Fungi spp.	0.37	0.18	0.17
Galium sp.	0.51	1.64	0.50
Geum allepicum	0	0	0.67
Helianthus sp.	0.11	0.18	0.75
Hepatica americana	0.17	0	0.08
Heuchera richardsonii	0.03	0	0
Iris, Blue flag iris	0.09	0	0.17
Labiatae family	0	2.09	5.33
Lactuca spp.	0.43	0.64	0
Lathyrus palustris	0.43	0.36	0
Lonicera sp.	0.17	0	0
Maianthenum canadense	1.74	1.0	1.5
Osmorhiza claytoni	6.97	1.64	0
Petasites palmatus	0.83	5.09	0
Polygonum spp.	0	0.27	3.92
Potentilla sp.	0.03	0	0.17
Prunus spp.	0.40	0.18	0
Pteridium aquilinum	1.46	0.55	0.50
Fern sp.	1.20	2.36	0.08
Pyrola virens	0.31	0.09	0.58
Quercus rubra	0.03	0	0
Ribes sp.	0	0.36	0.25
Rosaceae family	0.17	1.27	0.17
Rubus pubescens	1.80	0	0
Rubus strigosus	0.80	2.09	1.92
Rumex crispus	0	0	2.75
Sanicula merilandica	1.37	0.09	0
Smiliana racimosa	6.09	0.55	0
Solidago spp.	3.51	1.64	1.58
Spiraea alba	0	0	0.58
Streptopus roseus	0.43	0.27	0
Thalictrum dioica	0.89	0.91	0.25
Trillium grandiflorum	0.06	0	0.08
Heracleum maximum	0.37	0	0
Viburnum sp.	0.23	0.18	0
Viola sp.	0.54	0.18	1.83

the present study, and therefore no data other than the station number was recorded. These extraneous species included: least chipmunk (Tamias minimus), red squirrel (Tamiasciurus hudsonicus), raccoon (Procyon lotor), and least weasel (Mustela erminea).

The captures of target species totaled 168 individuals in 8 species. Insectivores included: arctic shrew (Sorex arcticus), masked shrew, (Sorex cinereus), and short-tailed shrew (Blarina brevicauda). Rodents included: red-backed vole (Clethrionomys gapperi), meadow vole (Microtus pennsylvanicus), deer mouse (Peromyscus maniculatus gracilis), meadow jumping mouse (Zapus hudsonicus), and woodland jumping mouse (Napeozapus insignis).

The most abundant species was the red-backed vole, with 53 individuals captured, representing 32.1% of all animals captured. The rarest species was the woodland jumping mouse with only 1 capture (Table 2).

Home range

Home ranges for male red-backed voles varied from 11.2 to 86.9 m^2 and averaged 40.1 m^2. Mean female home range was 13.6 m^2 (range = 9.4-17.5 m^2) (Table 3). Home range estimates for other species are given in Table 3. Male deer mice had the largest home range (mean = 142.7 m^2) and female red-backed voles the smallest (mean = 13.6 m^2).

Table 2. Small mammal species composition, Itasca study site, 1992.

SPECIES CAPTURED	n	% OF TOTAL
_B_. _brevicauda_	14	8.5
_S_. _arcticus_	3	1.8
_S_. _cinereus_	15	9.1
_P_. _maniculatus_	16	9.7
_C_. _gapperi_	53	32.1
_M_. _pennsylvanicus_	27	16.4
_N_. _insignis_	1	0.6
_Z_. _hudsonicus_	36	21.8
TOTAL INDIVIDUALS	165	101.0

Table 3. Summary of mean home range estimates (m^2, 95% of captures) of small mammals, Itasca study site, 1992.

SPECIES	SEX	n	MEAN (SD)	RANGE
B. brevicauda	F	1	43.5 (none)	43.5
P. maniculatus	M	3	142.7 (177.6)	37.6-347.7
C. gapperi	M	11	40.1 (77.9)	11.2-86.9
C. gapperi	F	4	13.6 (3.5)	9.4-17.5
M. pennsylvanicus	M	5	44.3 (19.4)	23.1-69.1
M. pennsylvanicus	F	3	15.3 (8.3)	5.9-21.7
Z. hudsonicus	M	5	39.6 (18.4)	21.7-65.2

Male deer mice showed the greatest variability in home range size (range 37.6-347.7 m^2). Males in general had larger home ranges than females (Table 3). Insufficient data were available to compute home range values for male or female masked shrews, male or female arctic shrews, male short-tailed shrews, female meadow jumping mice and female deer mice.

Distribution by habitat

Number and proportion of captures of each species are in Tables 4 and 5. The predominant species found in the wet meadow was the meadow vole, with 6.3 voles per 100 trap nights (Table 4), representing 66.9% of all mammal captures in this habitat. Not only did the meadow vole dominate over the number of captures for other species in the meadow, but 94.3% of its captures were made in the meadow (Table 5). The most predominant species in the aspen upland was the red-backed vole, with 4.8 red-backed voles captured per 100 trap nights (Table 4), accounting for 55.3% of all mammal captures in the aspen, and was captured most often overall in the aspen stand (66% of total red-backed vole captures, Table 5). The red-backed vole was the dominant species trapped overall, comprising 31.5% of all animals captured. Deer mice showed a greater frequency of occurance in the aspen stand, which is reflected in the distribution of their captures in the three habitats, with 89.1% being captured in

Table 4. Capture success (per 100 trap nights) of small mammals by habitat type, Itasca study site, 1992.

SPECIES	ASPEN	ECOTONE	WET MEADOW
B. brevicauda	0.55	0.21	0.17
S. arcticus	0.08	0	0.13
S. cinereus	0.34	0.17	0.13
P. maniculatus	2.61	0.19	0.13
C. gapperi	4.82	1.64	0.84
M. pennsylvanicus	0.13	0.25	6.30
N. insignis	0	0	0.06
Z. hudsonicus	1.72	0.95	1.02
TOTAL SUCCESS	10.25	3.41	8.78

Table 5. Percent of captures in each habitat type, by species, Itasca study site, 1992.

SPECIES	ASPEN	ECOTONE	WET MEADOW
B. brevicauda	59.0	22.7	18.2
S. arcticus	40.0	0	60.0
S. cinereus	53.0	26.7	20.0
P. maniculatus	89.1	6.5	4.3
C. gapperi	66.1	22.4	11.5
M. pennsylvanicus	1.9	3.8	94.3
Z. hudsonicus	46.6	25.9	27.7

the aspen (Table 4). Meadow jumping mice were trapped nearly half of the time in the forest (46.6% of its captures, Table 5). Only 1 woodland jumping mouse was captured in the study and was not included in the analysis. Short-tailed shrews were found primarily in the aspen forest with 0.55 captures per 100 trap nights (Table 4), accounting for 59% of its captures overall. The arctic shrew was very uncommon, with 5 captures total. The masked shrew was captured most often in the aspen with 0.34 captures per 100 trap nights (Table 4) accounting for 53% of its captures overall. Of all shrew captures, 85% were in pitfall traps.

Density and Sex Ratio

The densities of small mammals varied from 24.8/ha for the short-tailed shrew, to 117.4/ha for the meadow vole (Table 6). Density estimates for all species from this study are given in Table 6.

The sex ratio was skewed toward males for red-backed voles 5:1 (3:1 excluding transients), and for deer mice 15:1 (7:0 excluding transients). The sex ratio was skewed toward females for short-tailed shrews 2:5, and meadow jumping mice 5:10 (4:13 excluding transients). The sex ratios were more equal for the meadow vole with a 5:4 ratio, and the masked shrew with a 6:5 ratio (Table 7).

Table 6. Densities (n/ha) of small mammal species, Lake Itasca study site, 1992.

SPECIES	n	DENSITY (Schnabel index)
B. brevicauda	14	24.8
S. arcticus	3	3.7
S. cinereus	15	18.5[1]
P. maniculatus	16	24.8[2]
C. gapperi	53	52.0
M. pennsylvanicus	27	117.4[3]
Z. hudsonicus	36	61.2

1. Minimum number known to be alive (Hilborn et al. 1976) estimate was used because this species had no recaptures.

2. Only forest area used for calculation.

3. Only marsh area used for calculation.

Table 7. Sex ratio (males/female) of small mammal species captured on Itasca study site, 1992.

SPECIES CAPTURED	n	RATIO INCLUDING TRANSIENTS	RATIO EXCLUDING TRANSIENTS
B. brevicauda	14	0.4	NA
S. cinereus	15	1.2	NA
P. maniculatus	16	15.0	NA
C. gapperi	53	5.0	3.0
M. pennsylvanicus	27	1.3	NA
Z. insignis	1	NA	NA
Z. hudsonicus	36	0.5	0.3

DISCUSSION

Small mammal communities in temperate forests are usually dominated by one or two species, which will comprise 70% of all individuals trapped (Manville 1949, Richens 1974, Grant 1976, Nagorsen and Peterson 1981). Due to their broad ecological and geographic distributions, C. gapperi, P. maniculatus, and P. leucopus are often the most abundant small mammal species in temperate forests throughout North America (Kirkland 1985). In this study the red-backed vole dominated the community accounting for 33% of all individuals captured. It was the species caught most often in the aspen forest and ecotone while being the second most often captured in the meadow. This vole is water dependent (Kirkland 1990) because of its relatively inefficient kidneys (Getz 1968) and requires high water consumption (Merritt 1981); thus it must extract enough water from the environment via free water or through moisture found in food (seeds, roots, and berries) to survive. The trapping data indicate that they do utilize all three areas, each of which differ in the amount of free water available. However, they were caught most often in the forest (66.1%) which was the driest of the three habitats, which suggests that water may not be the limiting factor in this study area.

In this study the aspen forest was replete with cover and runways for small mammals, including blowdowns with exposed roots and their associated tunnels, scrub, litter, and decaying logs and stumps covered with moss. There were few blowdowns, less scrub, less litter, and virtually no decaying logs in the ecotone. Also, by definition, the ecotone was without any canopy on the meadow edge. The meadow consisted of large patches of pure sedge with very few shrubs or logs nearby for cover and runways. A correlation between the amount of cover provided by debris and abundance of red-backed voles was noted by Miller and Getz (1973), especially within lowland sites. This debris provides a safe harbor from avian predators and is also a repository for insects palatable to the red-back vole. The red-back has also been shown to prefer areas with rotting stumps, logs, loose litter (Gunderson 1959), and blow downs (Meierotto 1967) which were present in the aspen stand in this study.

The absence of preferred cover in the ecotone and meadow is reflected in the distribution of captures, with the majority of red-backed voles being captured in the forest (66.1%), followed by the ecotone (22.4%) and wet meadow (11.5%), respectively. It is also evident in the proportion of captures for each area, with red-backed voles accounting for 55.3% of all forest captures, 55.7% of all ecotone captures and only 13.5% of the wet meadow captures.

This is in agreement with studies showing this vole to be more of a forest species (Soper 1946, Butsch 1954, Gunderson 1959, Iverson et al. 1967), including low coniferous (Bailey 1929, Hatfield 1938, Manville 1949), mixed (Jackson 1961, Clough 1964, Doutt et al. 1966), and deciduous (Burt 1946, Gunderson and Beer 1953), and especially aspen stands (Hnatiuk 1967). The red-backed vole may also be found in shrubby areas (Bailey 1929, Sargeant and Marshall 1959). This is supported in this study by the frequency of occurrence in the ecotone (22.4% of its captures), and their dominance of the species captures in the ecotone (55.7% of ecotonal captures), because the ecotone is a shrubby transitional area between the forest and the wet meadow.

While Miller and Getz (1973) showed no correlation between abundance of red-backed voles and the amount or type of vegetation, Lovejoy (1975) has shown a correlation between <u>Rubus</u> species and abundance of voles. This relationship may be a factor in this study. There were two species of <u>Rubus</u> (raspberry and blackberry) common in the forest habitat which had the most red-backed vole captures (115), while only one species of <u>Rubus</u> (raspberry) was found in the ecotone (39 captures) and meadow (20 captures). This raspberry was found an average of 1 per station in the forest, 2 per station in the ecotone, and 2 per station in the meadow. When both species of <u>Rubus</u> are considered together, the forest has the highest average amount of <u>Rubus</u>

per station with an average value of 2.6. Meierotto (1967) studied a small mammal population in the southwest corner of Itasca Park. He found a positive association between the red-backed vole and plants such as Viburnum spp., and Thalictrum dioica. The abundance of these two plant species paralleled that of the red-backed vole in this study with highest populations of both in the forest, less in the ecotone and least in the meadow. Other factors influencing the distribution include; 1) the habit of meadow voles aggressively excluding the red-backed vole from grassland habitat in summer (Iverson and Turner 1972), and 2) the tendency of red-backed voles to be found more often near deciduous trees which provide food.

In this study the meadow jumping mouse was captured more often in the aspen stand than in the wet meadow or the ecotone. Iverson et al. (1967) reported them to prefer open areas like grasslands and aspen groves over mature woodlands. Studies have indicated that they prefer moist abandoned fields with a low undergrowth of grass or forbs (Quimby 1951, Getz 1961c), and they were also more populous in areas where grasses are the dominant vegetation (Krutzsch 1954). In this study there was a rich undergrowth of grass and forbs in the aspen forest which would be considered good habitat. Some studies indicate that moisture is a limiting factor in its distribution (Stoner 1918, Lyon 1936, Gunderson and Beer 1953, Dexter 1954, Sargeant and Marshall

1959, Getz 1961c, Jackson 1961, Peterson 1966). In regards to water requirements, the meadow jumping mice in this study were captured less often in the most moist habitat, the wet meadow. This indicates that there was an adequate amount of water in the forest. Other investigators have documented that a limiting factor is cover (Whitaker 1963, Getz 1961c), and that without an adequate amount of herbaceous ground cover meadow jumping mice will not be able to maintain a viable population (Whitaker 1972). There were abundant forbs and extensive cover provided in the aspen stand, which would be attractive to the meadow jumping mouse. Another possible factor influencing the distribution of the meadow jumping mice is food. They are seed eaters, and eat raspberries, blackberries and strawberries (Doutt et al. 1967). These berries were most abundant in the forest as were the jumping mice. Meadow jumping mice are hibernators and as such they were not captured in the October trapping session.

Meadow voles were almost exclusively captured in the grass-sedge dominated wet meadow (94.3% of all meadow vole captures), and they were the overall predominant species captured in the meadow (66.9% of all meadow species captures). They rarely ventured out of their preferred habitat to explore the ecotone, or the forest.

Studies on meadow voles have shown a positive association with grassland type habitat (Reich 1981, Johnson and Johnson 1982), and that they prefer grassland over woodland (Getz 1961b, Grant 1971, M'Closkey and Fieldwick 1975, Wrigley 1974, Yahner 1982, 1983) and their occurrence is positively correlated to grass cover and total cover (Hodgson 1972), and forb cover (Geier and Best 1980). The meadow vole is characteristically found in situations in which graminoid vegetation dominates (Bailey 1900, Lantz 1907, Pearson 1959, Getz 1961b, Pugh 1980), due in part to its reliance upon graminoids as its main food source (Getz 1961b, Banfield 1974). Other associations with plants have been reported. Whitaker et al. (1991) working just north of Itasca Park, have reported heavy use of Rumex crispus by the meadow vole. In my study this plant was only found in the wet meadow. Meierotto (1967) reported a positive association between meadow vole populations and the presence of Lathyrus palustris and Potentilla spp.. This was true for Potentilla sp. in my study but not for Lathyrus palustris whose distribution was inversely proportional to the distribution of the meadow voles. Within graminoid types, abundance of the meadow vole appears to be correlated with the amount of cover present (Blair 1940, Eadie 1953, Mossman 1955, LoBue and Darnell 1959, Pearson 1959, Getz 1961b, Douglass 1976). "One logical advantage of areas with more cover is increased protection from predation, particularly from avian or larger mammalian predators" (Getz 1970b:215). In addition to protection from predation, cover might limit intra-specific interactions, allow for diurnal activity in runways, influence microhabitat, and influence the microtine population cycle (Birney et al. 1976).

Meadow voles prefer mesic rather than xeric habitats (Findley 1951, Gunderson and Beer 1953, Getz 1960, 1961b, Murie 1969, Hodgson 1972, Wrigley 1974, and others), and will choose the wettest site available to them (Getz 1970a, Birney et al. 1976). This being said, it is not surprising that Birney et al. (1976) reported higher meadow vole population densities in a grass sedge marsh than in upland grassland in the same region. This was the habitat in which I found them to be most common.

Another factor that may be keeping the meadow vole in the meadow and out of the forest, is the high population of red-back voles in the forest. For instance, in a Canadian study (Morris 1969), the meadow vole used aspen stands where the red-backed vole was absent. Additionally, both species were found to coexist to some degree during the winter but during the summer the red-backed vole excluded the meadow vole. "It is apparent that either species in the absence of the other, can live in both habitats" (Iverson and Turner 1972:444). On the other hand, Sanderson (1950) indicates that even in isolated situations the meadow vole does not occur in forests if graminoid stands are available. Without an extended winter trapping season this question will remain unresolved. Another small mammal that preys upon meadow voles and was abundant in the forest is the short-tailed shrew. They have been shown to prey upon meadow voles (Schmidt 1931, Eadie 1944, 1948, 1952, Barbehenn 1958), and this may have added to their restriction to the wet meadow. They shared only 5 trap sites in this study. In general the meadow vole occures more often and dominates in low wet meadows (Enders 1930, Grant 1971, Zimmerman 1965, Hodgson 1972), and this is what was found in this study.

The deer mouse was captured most often in the upland aspen habitat (89.1% of total captures). In Minnesota, the deer mouse is often found in coniferous forests (Gunderson and Beer 1953). This would seem an enigma were it not for Iverson et al. (1967), who captured the deer mouse in a deciduous forest in northwestern Minnesota, that had once been coniferous. The present study site, like much of the surrounding area, consisted of clear cut coniferous forest now replaced by aspen. There was only a single pine tree left on the entire trap grid. Dice (1925) and Cahn (1937), found the deer mouse to be more abundant in hardwood forests than in coniferous ones. Jackson (1961) found the deer mouse in deciduous, mixed coniferous forests and even in spruce swamps. One factor that seems more generally applicable to both types of forest is the preference for drier, more open habitats (Brown 1964, Baker 1968, Pendleton 1982). Their ability to exploit this drier habitat is due in part to their highly efficient kidneys which can concentrate their urine twice that of the red-backed vole (Getz 1968). Deer mice were shown to prefer a sub-climax community with less herbaceous cover (like that found in the aspen stand) to an Andropogon-type climax (like the wet meadow) (Johnson 1926, Miller and Getz 1977). Other plant associations have been noted by Meierotto (1967). He found a positive association between deer mice and Prunus spp., Ribes sp., Streptopus roseus, and Sanicula marilandica. In my study all of these plants were most abundant in the aspen forest except Ribes. He also found a negative association between deer mice and Corylus spp. and Aster spp.. The distribution of Corylus spp. did not follow this pattern but the abundance of Aster spp. did, with the most deer mice being captured where there was the least amount of Aster spp.. According to Wecker (1963:321), "deer mice born in the forest would have a strong genetic preference for this habitat, reinforced by early experience". Although they apparently prefer the forest to the marsh they can utilize wetland edges (Lindell 1971, Wilhelm et al. 1981). In addition to the undesirable heavy cover in the marsh the presence of meadow voles in the marsh may also keep the deer mice away (Redfield et al. 1977, Abramsky et al. 1979). Wirtz and Pearson (1960) reported interspecific aggression between these two species and noted that high population levels of meadow voles are consistent with low populations of deer mice.

Sorex species have been reported as being trap-shy when investigators have tried to use spring-loaded traps to capture them (Wrigley et al. 1979), which might be exacerbated by their small size, being insufficient to trigger a trap. Also they have exhibited bait avoidance (Wrigley et al. 1979) which often is simply a refusal to eat or be attracted to a food not found naturally (i.e., domestic grains or processed peanuts). This problem was countered in this study by using a more natural bait (insect larvae) and pitfall traps to accompany the spring-loaded traps. Many researchers have shown the superiority of using pitfall traps alone or in tandem with other traps, over using spring-loaded traps alone (Hudson and Solf 1959, Aulak 1967, Brown 1967, Chelkowska 1967, Pucek 1969, Andrzejewski and Rajska 1972, Briese and Smith 1974, Wolfe and Esher 1981, Bury and Corn 1987, Belk et al. 1988). In this study the use of pitfalls was crucial, since 85% of all Sorex captures were in pitfalls. If this method were not used then the population density would have been grossly underestimated.

Masked shrews have been found in almost as many habitats as there have been studies done on them (Bailey 1929, Peterson 1966, Brown 1967, Iverson et al. 1967, Wrigley et al. 1979, Yahner 1982, and others). Nevertheless many studies agree that they are often more common in moister habitats (Cahn 1937, Manville 1949, Brown and

Lanning 1954, Jackson 1961), including habitats dominated by sedges and rushes (Getz 1961a, Spencer and Pettus 1966, Brown 1967, Clark 1973, Wrigley 1974, Wrigley et al. 1979), like that found in the wet meadow. In this study masked shrews were captured most often in the aspen (53%), 26.7% in the ecotone and 20% in the wet meadow, so my study did not show this apparent preference for the wettest area available. Meierotto (1967) in Itasca noted a positive correlation between the number of windfalls in an area and the number of masked shrews. This was true in my study, with windfalls and masked shrews both being most abundant in the aspen stand, and least abundant in the wet meadow. Another factor responsible for the low numbers of masked shrews in the marsh, could be due in part to the high numbers of meadow voles in the marsh. Platt and Blakely (1973) have noted the short-tailed shrew to have a negative effect on the masked shrew, which was apparent in this study as they shared only a single trap location.

In this study 3 arctic shrews were captured five times, twice in the aspen habitat, and 3 times in the wet meadow. The arctic shrew is a very uncommon species in the park. Until 1946, 8 specimens comprised its known occurrence in the park (Quimby 1943, Sargeant and Marshall 1959). Since that time, three specimens have been documented in research reports filed at the Itasca Biological Station, and two study skins were added to the vertebrate collection at the station.

Finding this uncommon species required using an effective bait and placing the traps in an area capable of supporting a population of arctic shrews. The arctic shrew has been described as a boreal species by Hoffman and Jones (1968). Baird et al. (1983) documented an apparent preference for non-forested areas, either marshes or grassy clearings within forests. The arctic shrew is common in moist habitats, including tamarack and spruce swamps (Burt 1946, Gunderson and Beer 1953, Jackson 1961), and marshes (Bailey 1929, Soper 1961, Peterson 1966, Iverson et al. 1967). They were captured in a wet meadow by Nagorsen and Peterson (1981). In previous studies at Itasca an arctic shrew was captured on the edge of a marsh, while two others were captured in a wet lowland area. Of the two study skins residing at the Itasca vertebrate museum, one was captured in a lowland forest with dense undergrowth while the other was caught in a cattail marsh at the edge of a sewage lagoon. Jackson (1961) and Soper (1961) captured them in a willow-alder fen. The tendency to find arctic shrews in wet, low, grass-sedge marsh/willow-alder fen type habitats was borne out in my study.

The reported habitat occupied by the short-tailed shrew is quite broad (Cahn 1937, Odum 1949, Jameson 1949, Barger 1957, Pruitt 1959, Getz 1961a, Jackson 1961, Wrigley et al.

1979, Yahner 1982, Jones et al. 1983). George et al. (1986) found them most common in areas with 50% or greater herbaceous cover. Pendleton (1982) showed a positive correlation between the occurrence of short-tailed shrews and litter depth, forb cover, and sedge cover, with a negative correlation with dead cover and bare soil. They are abundant in moist habitats, especially grass-sedge meadows (Getz 1961a, Wrigley et al. 1979). However they also avoid areas inundated with water (Burt 1940). This was an influence in this study, with the majority of captures made outside of the wet meadow, which was very wet. Although Geier and Best (1980) found their occurrence to be positively correlated to grassy cover, it was probably too wet in the wet meadow for them in this study. In this study Blarina were captured most often in the aspen forest, 13 times (59% of total captures). This is in agreement with researchers who generally consider the short-tail shrew to be most common in wooded situations (Enders 1930, Lewis 1940, Jameson 1949, Gunderson and Beer 1953, Peterson 1966), especially moist forests (Dice 1925, Burt 1946). Burt (1940) showed them to be less common in dry habitats with scant cover or vegetation. The aspen stand was interspersed with fallen, rotting moss-covered logs, high numbers of shrubs, ground litter, and had the highest plant species richness (59 species). Moist microhabitats were spread throughout the stand in the form of moss, rotting wood, and depressions in the topography. Pruitt (1959) has suggested that the preference shown for moist rotted debris (i.e. logs, stumps, etc.) is related to their strong tendency to be fossorial but without the special adaptations required to be truly fossorial. So they live in an area where the substrate is easily navigable (i.e. under moss, heavy grass), and/or the substrate does not require advanced digging abilities to tunnel through (i.e. rotted wood, preexisting runways, etc.) like that required to excavate bare compacted soil. Along these lines Meierotto (1967) found the short-tailed shrew associated with windfalls. This was true on my study site as well.

It is well documented that meadow voles may avoid entering traps newly placed in their environment (Chitty and Kempson 1949). This may also be true for short-tailed shrews as well, which may be wary of the initial disturbance involved during the set-up of a trap line, then become acclimated to the disturbance. Gentry et al. (1971) did not capture a short-tailed shrew for 13 days, while it took Smith et al. (1980) 11 days before the first short-tailed shrew appeared in their traps, and it took 7 days before one appeared in mine.

Red-backed vole density was estimated to be 52.0/ha. Gunderson (1962), in a study of the red-backed vole in southeastern Minnesota, found between 0 and 28/ha in a tamarack-white cedar bog, with a peak population in summer.

The red-backed vole population in my study was somewhat higher than this estimate, possibly due to a high point in the vole population cycle. The meadow vole population was estimated to be 35.8/ha for the entire grid, but due to the species limited use of non-meadow habitat a population estimate for meadow area alone of 117.4/ha, would be a more accurate estimate. Taitt and Krebs (1985), summarized population patterns in the meadow vole and derived a range of 57-127/ha annually, with cyclic populations ranging from 23-156/ha. The meadow jumping mice were less abundant than either of the voles, with an estimated density of 61.2/ha. This is compared to estimates by Quimby (1951) who also studied them at Itasca, and estimated their densities at 17.5/ha for males and 11.9/ha for females. He also showed that the number of jumping mice in any area may vary considerably from year to year. Deer mice were uncommon on the grid, with an estimated density of 14.9/ha. They, like the meadow vole did not utilize all three habitats. They were most abundant in the aspen (85% of its captures), so a more accurate density estimate was calculated for the aspen stand alone at 24.8/ha. This estimate is very close to that of Galindo and Krebs (1985) who found 2-16 deer mice/ha for an over-wintered population, with the first litters added to the trappable population in late June and the second litter becoming trappable in early August, resulting in a peak population of between 24 and 30 deer mice per hectare.

Approximately 24.8 short-tailed shrews/ha were present in this study. This falls within the range estimated by Pendleton (1982) of 23.6-32.4/ha. Masked shrew density approximated 18.5/ha, which is in agreement with Pendleton (1982) who found 20.6/ha. Arctic shrews were very uncommon so the estimate of 3.7/ha is only tentative.

Mean home range of male red-backed voles in this study (40.1 m^2) was found to be larger than that of females (13.6 m^2). Data on home ranges were reviewed by Merritt and Merritt (1978), with means for the red-backed vole varying from 0.01 to 0.5 hectares (100-5,000 m^2). It is not known why the home range estimates in this study were below that reported.

Mean home range estimate of male meadow jumping mice was 39.6 m^2. No home range was estimated for females. Quimby (1951) estimated meadow jumping mouse home range at Itasca Park, and listed mean values of 0.17 ha (1,700 m^2) for males and 0.15 ha (1,500 m^2) for females. Blair (1940) in Michigan, estimated home range for males at 0.32-0.40 ha (3,200-4,000m^2) and 0.33-0.42 ha (3,300-4,200 m^2) for females. It is not known why the home range estimates in this study were below that reported. Quimby (1941) has suggested that the environment plays a major role in determining the size and that the shape of home ranges is determined by terrain.

Mean home range of male meadow voles in this study (44.25 m^2) was found to be larger than that of females (15.34 m^2). Getz (1961d) cited the reasons that male home range was larger than that of the female were due in part to the female taking care of young at the nest and so its movements are restricted and the males moving over larger areas looking for mates. Getz (1970b) studied meadow jumping mice in a marsh habitat in Wisconsin, and estimated home range for males as 465-700 m^2 and 310-530 m^2 for females. Madison (1980) working in an old field in Virginia estimated male home range at 192.3 m^2 (+/- 109.7 m^2) and 68.6 m^2 (+/- 39.4 m^2). I believe the reason the meadow voles in this study had such small home ranges in comparison to the literature is that the meadow was an ideal habitat and there was less optimum habitat in the form of forest on three sides and an inundated marsh on the remaining side. Another factor might be a bias in trappability of the voles. In a study on <u>Microtus</u> <u>californicus</u> Krebs (1966:242) stated that "live trapping estimates are low because the probability of catching a tagged vole is greater than that of catching an untagged vole."

Mean home range estimate of deer mice was 142.66 m^2. No home range was estimated for females. Blair (1940) reported home range values for males at 0.255 ha (2,550 m^2) and 0.206 ha (2,063 m^2) for females. In another study Blair (1942) reported home range values for males at 0.93 ha

(9,300 m^2) and 0.56 ha (5,600 m^2) for females. The home range estimates in this study are low due in part to the size of the area trapped in this study (0.486 ha) which was smaller than the average home range size for a deer mouse as reported in the literature. This would preclude the possibility of having capture sites throughout its home range and so only a portion of the range would be determined. In addition, small home ranges can indicate high population densities and/or favorable habitats for this species (Getz 1961d).

Mean home range estimate for female short-tailed shrews was 43.46 m^2. No home range was estimated for males. Blair (1940, 1941) estimated home range to be around 2.5 ha (25,000 m^2) on average, while Buckner (1966) found home ranges from 40 to 9,000 m^2. My estimates are more in agreement with Buckner's estimate.

The sample size for arctic shrews was too small to generate a home range estimate. There were no recaptures for the masked shrew so no home range estimate could be made.

The hidden complexity of a scenic area in Itasca State Park was brought out in this study. The small mammals found in this area were not uncharacteristic nor did any represent an extension of its range. But they did gain my interest and respect during this research. The deer mice were found where they would be expected, in the upland forest; the red-back vole was ubiquitous; the meadow vole was restricted to the fen. A suggested future study would be to eliminate all the red-back voles to see if the meadow vole expands into the upland area when not excluded by red-backed voles. The jumping mice were found in the forest which was compatible with their open and moist habitat requirements. Short-tailed shrew captures indicated an apparent preference for the forest. This fits well with visual observations of this shrew crawling under mats of moss looking for food, occasionally surfacing through a "shrew hole." Since quantities of moss did not exist in the ecotone or meadow, the absence of high numbers of short-tailed shrews in these other habitats is not surprising. Shrews were trapped using more refined and specialized techniques than ordinary capture-recapture studies. The number of arctic shrews captured was less than expected, but still quite satisfying considering the distinct possibility of never catching one without the most appropriate protocol as used in this study.

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